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Summary of Survival Data from Juvenile Coho Salmon in the Klamath River, Northern California, 2006

Open-File Report 2007–1023

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Cover: Photograph of Klamath River looking downstream near its confluence with the Salmon River, northern California. (Photograph taken by Philip Haner, U.S. Geological Survey, Cook, Washington, 2006.)

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Summary of Survival Data from Juvenile Coho Salmon in the Klamath River, Northern California, 2006

by John W. Beeman

Abstract

Little is known about the survival of ESA-listed juvenile coho salmon during their seaward migration in the lower Klamath River. In 2006, the Bureau of Reclamation funded a study to estimate the survival of radio-tagged juvenile coho salmon in the Klamath River downstream of Iron Gate Dam. A series of models were evaluated to determine if survival varied between hatchery and wild fish and among several river reaches between the dam river kilometer 33, a total distance of 276 kilometers. The results from 2006, the first year of study, indicated little support for differences in survival between hatchery and wild fish and lower survival in the most upstream reach than in those farther downstream. This document is a brief summary of survival results to date.

Introduction

In 2006, the U.S. Geological Survey (USGS) participated in a cooperative study to estimate survival of juvenile coho salmon in the lower Klamath River, northern California. The purpose of the study was to provide information about the relation between survival of juvenile coho salmon and river discharge in the Klamath River downstream of Iron Gate Dam (river kilometer [rkm] 310). The study fish were part of the Southern Oregon/Northern California Coasts Evolutionary Significant Unit of coho salmon listed as Threatened under the Endangered Species Act in 1997. The study was a collaboration among the USGS and, listed in alphabetical order, the Fish and Wildlife Service, the Karuk Tribe of California, and the Yurok Tribe. The work was funded by the Bureau of Reclamation, Klamath Falls Basin Office. This report is a brief summary of the survival results to date.

We estimated apparent survivals of radio-tagged juvenile coho salmon in the Klamath River downstream of Iron Gate Dam, northern California in 2006 using paired-release and single-release methods; both are based on Cormack-Jolly-Seber capture-mark-recapture models (Cormack, 1964; Jolly, 1965; Seber, 1965). Apparent survival is the probability that an animal remains available for recapture. In the context of this study, apparent survival is the joint probability that the animal is both alive and migrates through the study area. As such, fish that stop migrating, or travel to areas outside the mainstem Klamath River and do not return during the study are counted as mortalities. All references to 'survival' in this report refer to apparent survival.

To review 2006 activities, we released radio-tagged juvenile coho salmon (*Oncorhynchus kisutch*) of wild and hatchery origin separated into treatment and control experimental groups. The wild fish were obtained at the rotary trap in the Shasta River operated by the California Department of Fish and Game and the hatchery fish came from Iron Gate Hatchery. The treatment groups were released into the Klamath River at the hatchery (rkm 309) and the control groups were released into the Shasta River near its confluence with the Klamath River (rkm 288; fig. 1).

The purpose of the two experimental groups was to enable us to estimate survival of fish in the Klamath River from near Iron Gate Dam to the Shasta River, the first major tributary, without the potential effects of latent tagging and handling mortality. The paired-release design permits this and is described in detail in Burnham and others (1987). Latent mortality from tagging and handling, if present and expressed shortly after release, is included in overall mortality in other designs, and can result in an overestimate of the mortality associated with the treatment of interest. Relative estimates of survival were calculated using the paired-release design from the two experimental groups of wild and hatchery origin fish in each of the first three reaches. The survival estimates are "relative," because they are calculated as the treatment survival divided by the control survival, hence they are the treatment survival relative to the control survival. In the first reach, the relative estimate reflects the survival of the treatment group from release at Iron Gate Hatchery to the release point of the control group at the Shasta River, a distance of 21 km, and is based on the survival of each group from release to the Scott River detection site (fig. 2). In the next two reaches, the estimates are the survival of the treatment group divided by the control group over the entire reach, because both groups traveled the same distance. These can be useful to determine if there are tagging and handling effects that are not expressed within the first reach.

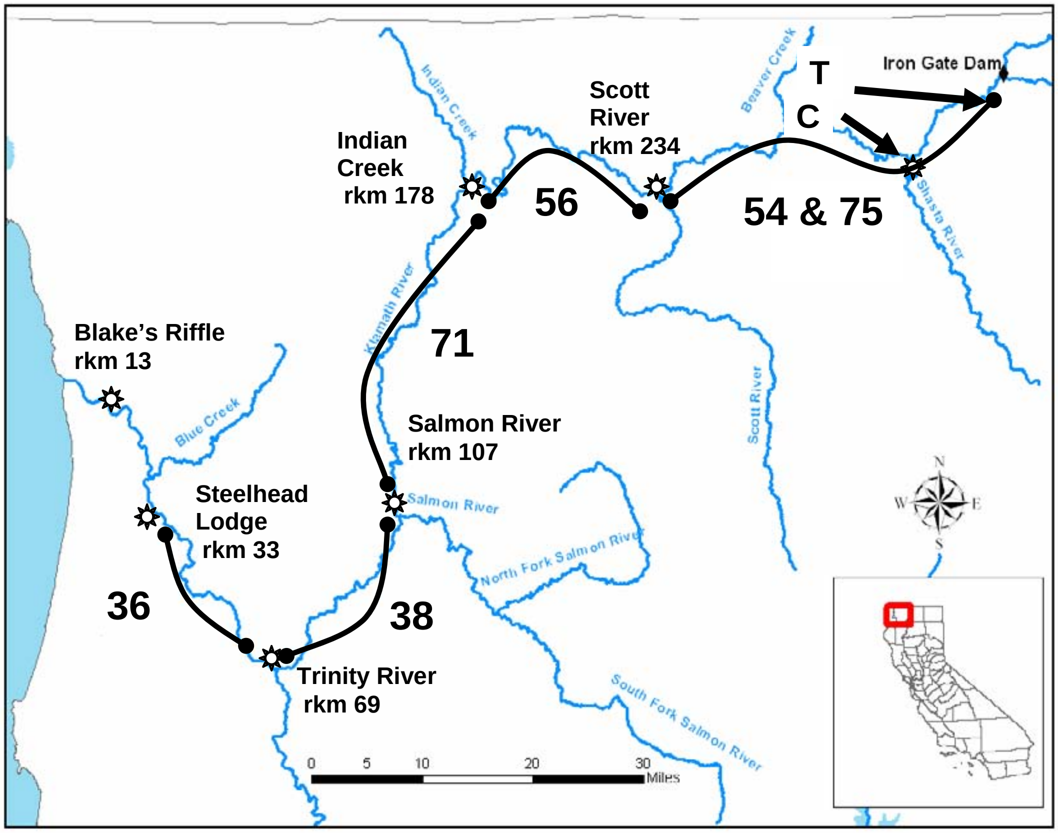

Figure 1. Study area of the Klamath River juvenile coho salmon survival study, northern California, 2006. Locations of treatment (T) and control (C) releases are indicated by arrows and detection sites are indicated by ☼. Bold numbers indicate the lengths of each reach in kilometers. Figure modified from U.S Fish and Wildlife Service, Arcata, CA., 2006.

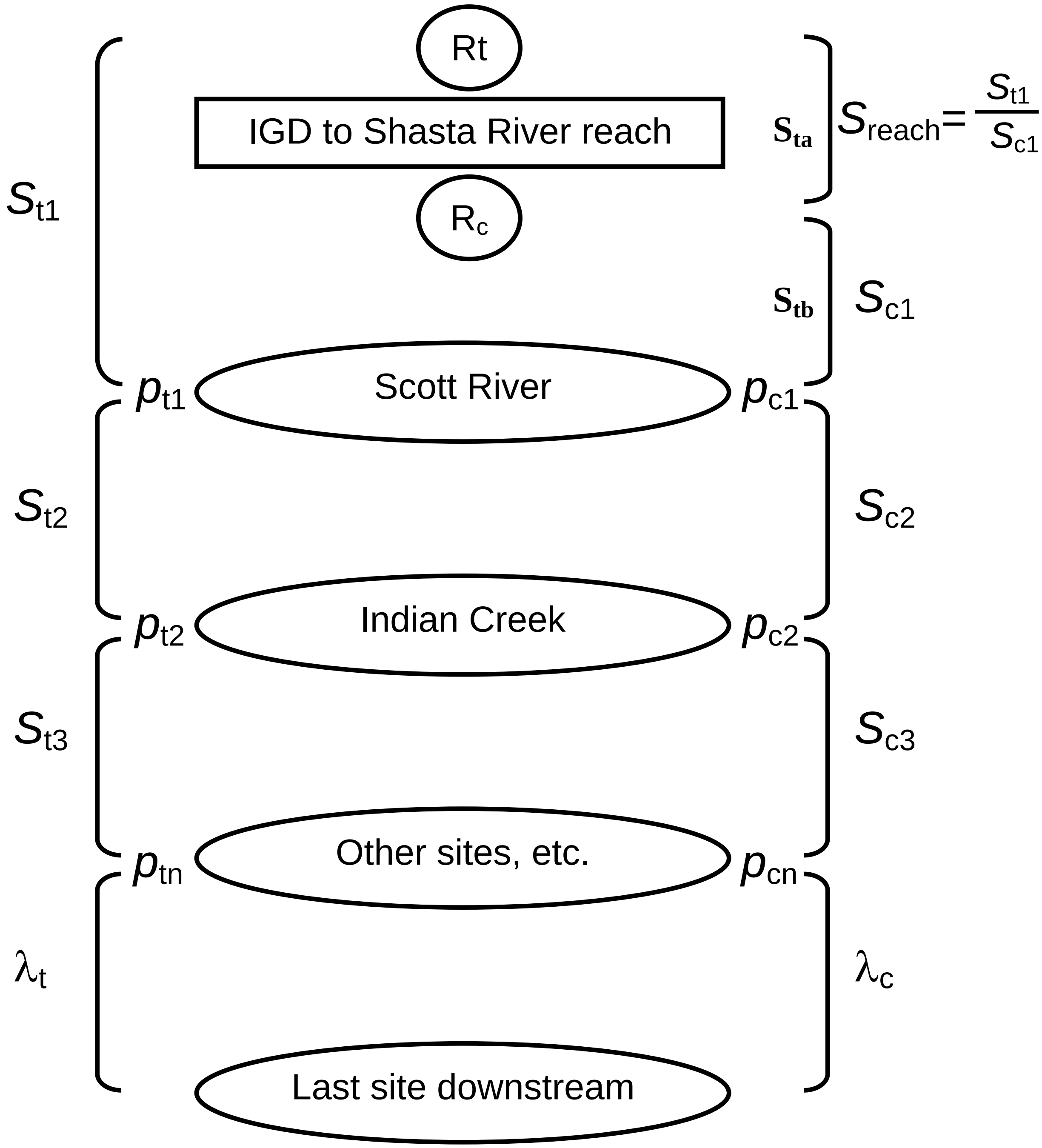

Figure 2. Schematic of the paired-release-survival model for the Klamath River juvenile coho study, northern California. Test fish released near Iron Gate Dam (IDG) were paired with control fish released near the Shasta River. The location of the control fish release is based on the definition of the reach of interest; the Shasta River was used in 2006. Survival from release near the dam to the Shasta River (S_{reach}) was measured relative to the control groups released near the Shasta River (Rc), canceling out effects of survival due to tagging and handling. Survival from there to and between the other sites, other than the last one, can be estimated as well, with the method depending on the assumptions that can be satisfied. Only the joint probability of capture and survival (λ) can be estimated in the last reach.

Survival of Juvenile Coho Salmon from Iron Gate Hatchery to the Shasta River

A series of models was created and ordered in terms of parsimony using the program MARK (White and Burnham, 1999). The analysis included a suite of models describing capture probabilities and survival of fish from the two experimental groups in each of the first three reaches. The models were ranked using Akaike Information Criterion (AIC) methods to determine the models that were best supported by the data. Estimates of capture probabilities and survivals were obtained via multimodel averaging, because several models were supported by the data. In multimodel averaging, models are weighted according to their AIC values and those with greater weights (for example, more supported by the data) contribute more to the result. The general methods are described in Burnham and Anderson (1998). Tests of model fit indicated moderate overdispersion in the data, which commonly is caused by heterogeneity. Overdispersion indicates that the variance may be underestimated. We therefore used a variance inflation factor, “c-hat”, of 1.305 to correct for the over dispersion in the data from hatchery fish and 1.536 in the data from wild fish (derived with program MARK using the median c-hat procedure). This is a common issue and does not indicate a problem with the fit of the model to the data.

The relative survival estimates and their confidence intervals are included in table 1. Each of the estimates is near 1.0 and their confidence intervals overlap 1.0 considerably. We can conclude from this that the survival of the treatment groups from release to the Shasta River was high, but the confidence intervals around the estimates are wide. The estimates in reaches two and three also are near 1.0, and the current data do not support differential tagging and handling mortality being expressed in treatment and control fish through these reaches. Thus, examination of reaches further from the release sites was not warranted.

Table 1. Estimated relative apparent survivals, standard errors, and 95-percent confidence intervals of radio-tagged juvenile coho salmon in each of the first three study reaches in the Klamath River, northern California, spring 2006.

[Data are from 157 wild fish and 116 hatchery fish released from April 25 through May 16, 2006. Results are based on the ratio of treatment group survival divided by the control group survival within each reach. Treatment fish were released at Iron Gate Hatchery (rkm 309) and control fish were released at the confluence of the Klamath and Shasta Rivers (rkm 288). As such, the first reach represents survival of the treatment group from Iron Gate Hatchery to the control release site. Both groups traveled the same distance through the remaining reaches. These are preliminary estimates generated on December 26, 2006, by John Beeman, U.S. Geological Survey, Western Fisheries Research Center]

Reach	Description	Reach length (km)	Relative apparent survival	Standard error	95-percent confidence interval	
					Lower	Upper
		Wild Origin				
1	Iron Gate Hatchery to Shasta River	21	1.101	0.123	0.860	1.343
2	Scott River to Indian Creek (rkm 178)	56	0.987	0.088	0.815	1.160
3	Indian Creek to Salmon River (rkm 107)	71	1.000	0.055	0.892	1.109
		Hatchery Origin				
1	Iron Gate Hatchery to Shasta River	21	0.995	0.079	0.840	1.149
2	Scott River to Indian Creek (rkm 178)	56	0.986	0.053	0.882	1.091
3	Indian Creek to Salmon River (rkm 107)	71	0.999	0.041	0.918	1.079

Survival of Juvenile Coho Salmon Through River Reaches

Survivals through each of the first five reaches and over them all were estimated using the single-release design. There were four objectives in this analysis. They were to determine if survival differed (1) between wild and hatchery fish, (2) between treatment and control experimental groups, (3) among reaches and, (4) to estimate the survival over the entire study area. The modeling approach was similar to that used for the paired-release analyses. In this analysis, the models were ranked and assessed based on the order of the ranking and by the error associated with their slopes describing the various effects (for example, the effect of origin on survival). The capture probabilities of nearly all models were specified similarly and were allowed to vary between origins and among reaches.

Four of the seven models evaluated were reasonably supported by the data (table 2). Similar support of several models indicated uncertainty in model selection. Model selection uncertainty means the "best" model from this analysis might not remain the "best" model if the experiment were repeated, and indicates that the models, given these data, are insufficient to distinguish among the various factors, and/or the factors are trivially different. Tests of model fit indicated moderate overdispersion in the data. We therefore used a variance inflation factor "c-hat" of 1.348 to correct for this (derived with the program MARK using the median c-hat procedure).

The top four models included those in which survival could vary by various combinations of reach, group, and origin. The model with the most support received about twice the weight of the second, three times the weight of the third, and five times the weight of the fourth (see QAICc weights in table 2). The last two models received less than 20 times the weight of the first and are essentially not supported by the data. The model with the largest weight allowed survival to vary among reaches, but not by origin or group. The next three models included reach and various additive effects of experimental group in the first reach (GroupAcute in table 2), origin, and a combination of all three. However, the coefficients within these models were imprecise, indicating the effects they described were poorly supported by the models given the data available. Consequently, results from this first year of study show little support for differences between experimental groups in the first reach, or differences in survival between wild and hatchery fish. We therefore estimated the survival within each reach, and subsequently over all reaches, using the output from the most supported model (the top row in table 2). An alternative method would be to generate estimates of reach survivals for each of the four combinations of origin and group after multimodel averaging, but the estimates from the two methods are essentially identical in this case.

Table 2. Model summary from analyses of apparent survival and capture probabilities to estimate reach survivals.

[Models are based on data from 157 wild fish and 116 hatchery fish released from April 25 through May 16, 2006. Model descriptions include factors allowed to vary within apparent survival (Phi) and capture probabilities (P), including reach, group (treatment or control), and origin (wild or hatchery). GroupAcute denotes a model factor for an acute group effect in the first reach only. Rankings are based on QAICc, a modification of Akaike Information Criterion for small samples and adjustments of extra binomial variation. A '+' between factors indicates an additive effect, '*' denotes a multiplicative effect. The global model includes multiplicative effects of all factors. Number of parameters denotes the number of estimable parameters in the model + 1 for the overdispersion adjustment]

Model	QAICc	Delta QAICc	QAICc weights	Model likelihood	Number of parameters	QDeviance
{Phi(Reach), P(Reach +Origin)}	1201.57	0.00	0.45	1.00	13	172.12
{Phi(GroupAcute + Reach), P(Reach + Origin)}	1202.67	1.10	0.26	0.58	14	171.17
{Phi(Reach + Origin), P(Reach + Origin)}	1203.58	2.01	0.17	0.37	14	172.08
{Phi(Reach + Origin + GroupAcute), P(Reach + Origin)}	1204.69	3.12	0.10	0.21	15	171.13
{Phi(Group*Origin + Reach), P(Reach + Origin)}	1207.46	5.89	0.02	0.05	16	171.83
{Phi(Origin*Group*Reach), P(Reach + Origin)}	1220.68	19.12	0.00	0.00	28	159.97
{global model}	1243.80	42.24	0.00	0.00	45	146.49

The overall (pooling origins and groups) estimates of survival were similar in most reaches (table 3). The point estimates ranged from 0.837 to 1.000 and the 95-percent confidence intervals were approximately ±5 percent. The lowest point estimate was from the first reach (0.837, 95-percent CI 0.776 to 0.893), which also is the reach fish spent the most time within (release to Scott River). The highest point estimate was in the fourth reach, Salmon River to Trinity River (1.000, 95-percent CI 0.966 to 1.000), a reach fish spent little time in. The overall estimate of survival from rkm 309 to rkm 33, taken as the product of the individual reach estimates, was 0.684 (95-percent CI 0.613 to 0.756). It is important to realize the estimates for each reach were not scaled by the length of each reach and are therefore not directly comparable to one another. These estimates are the first available for juvenile salmonids in the lower Klamath River and as such there are no others for direct comparison. However, the overall estimate is similar to those of juvenile salmonids migrating in the Columbia and Snake rivers on a "per kilometer" basis.

Table 3. Estimated apparent survivals and profile likelihood confidence intervals of radio-tagged juvenile coho salmon in five study reaches of the Klamath River, northern California, spring 2006.

[Results are based on data from 157 wild fish and 116 hatchery fish released from April 25 through May 16, 2006. Results are based on pooling fish of hatchery and wild origin and treatment and control groups. Data for the overall result was calculated as the product of the reach estimates with variance estimated using the delta method. Length of reach 1 was 54 km for the control group and 75 km for the treatment group. Data are preliminary estimates from December 21, 2006, by John Beeman, U.S. Geological Survey, Western Fisheries Research Center]

Reach	Description	Reach length (km)	Apparent survival	Standard error	95-percent confidence interval	
					Lower	Upper
1	Release to Scott River (rkm 234)	54 and 75	0.837	0.026	0.776	0.893
2	Scott River to Indian Creek (rkm 178)	56	0.916	0.024	0.854	0.961
3	Indian Creek to Salmon River (rkm 107)	71	0.938	0.019	0.887	0.973
4	Salmon River to Trinity River (rkm 69)	38	1.000	7.3E-07	0.966	1.000
5	Trinity River to Steelhead Lodge (rkm 33)	36	0.951	0.025	0.886	0.997
Overall	Release to Steelhead Lodge	276	0.684	0.037	0.613	0.756

Summary

The apparent survival of radio-tagged juvenile coho salmon in the lower Klamath River in 2006 was estimated using mark-recapture methods. This was the first year of a multi-year study. No latent effects of tagging and handling on survival were evident. The current data and models indicate little support for a survival difference between hatchery and wild fish in 2006, but considerable model uncertainty exists. Survival was lower in the reach from Iron Gate Hatchery to the Scott River than in reaches farther downstream. The overall estimate of survival from Iron Gate Dam to river kilometer 33 was 0.684 (95-percent CI 0.613 to 0.756).

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References Cited

Burnham, K.P., and Anderson, D.R., 1998, Model selection and multimodel inference: A practical information-theoretic approach: Springer Verlag, New York, 488 p.

Burnham, K.P., Anderson, D.R., White, G.C., Brownie, C., and Pollock, K.H., 1987, Design and analysis methods for fish survival experiments based on release-recapture: American Fisheries Society Monograph 5, American Fisheries Society, Bethesda, Maryland, 737 p.

Cormack, R.M., 1964, Estimates of survival from the sighting of marked animals: Biometrika, v. 51, no. 3/4, p. 429-438.

Jolly, G.M., 1965, Explicit estimates from capture-recapture data with both death and immigration-stochastic model: Biometrika, v. 52, no. 1/2, p. 225-247.

Seber, G.A.F., 1965, A note on the multiple-recapture census: Biometrika, v. 52, no. 1/2, p. 249-259.

White, G.C., and Burnham, K.P., 1999, Program MARK: survival estimation from populations of marked animals: Bird Study 46 Supplement, p. 120-138.

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